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EFFECT OF VIBRATIONAL ENERGY ON RESIDUAL STRESSES IN WELDMENTS AND FORGINGS

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COLUMBUS, OHIO 43201

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Director

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EFFECT OF VIBRATIONAL ENERGY ON RESIDUAL STRESSES IN WELDMENTS AND FORGINGS

J. E. Campbell

SUMMARY

Vibrating welded and hot- and cold-worked components at their resonant frequencies can cause a redistribution of residual stresses under certain conditions. However, indiscriminate use of such vibrations to cause relief of residual stresses is not recommended because (1) stress relief equivalent to that obtained by thermal stress relieving is not achieved and (2) if there are flaws or stress raisers in the components, fatigue cracks can be initiated at these locations. Redistribution or modification of the residual stress patterns by means of repeated vibrations can be obtained and might be beneficial for certain components as long as a qualitative or quantitative study has been made of the residual stress patterns before and after vibrating prototype components. Nondestructive inspection is recommended both before and after the vibration treatment.

INTRODUCTION

A number of inquiries regarding the use of currently-available commercial equipment claimed to promote stress relief of welded assemblies, forgings, castings, and other components have been received by the Defense Metals Information Center. For thermal stress relieving treatments for large weldments, as an example, large stress relieving furnaces are required, and the weldments must be exposed to the heating and cooling cycle for a considerable length of time. If stress relieving could be accomplished by some other method, such as vibrating the component at resonant frequency, considerable processing time and expense could be saved. This accounts for the interest that has been shown in the commercial equipment. DMIC has collected as much of the information on use and performance of this equipment as was available at the time that this technical note was issued. Documentary evidence regarding the stress redistribution and the performance of the vibration-processed components is very limited.

DISCUSSION

Equipment is available for vibrating weldments, forgings, and other metal components at their resonant frequencies. Use of the equipment is claimed to cause stress relief depending on the length of time used for the treatment and on the weight of the components.[1,2] Since the equipment is simple and power requirements are small, costs for purchasing and using the vibrating equipment are low as compared with the cost of stress relieving furnaces. The total processing time as recommended by the manufacturer is in the order of 20 to 30 minutes for many of the components for which it might be used. These are much shorter time periods than the usual thermal stress relieving cycles.

In order to cause stress relief in a metal component that has high residual stresses, some form of plastic deformation or micro-yielding must occur in the localized areas of maximum residual stress. This can occur during thermal stress relieving because the yield strength at the elevated temperature is usually lower than the maximum residual stress level. Localized micro-yielding tends to relax the residual stresses.

The process by which residual stresses are redistributed during repeated stressing at resonant frequency is not well known. However, the combined stresses, composed of the sum of the residual stresses and the dynamic stresses caused by the vibrations, are assumed to reach a level that would cause some micro-yielding in the localized areas where the residual stresses were highest. Therefore, information as to extent and location of residual stresses would be desirable for the most effective use of vibrational stress-relief techniques. Information on the instantaneous stresses in certain areas resulting from specific vibrational modes at resonance along with the effect of power input on the vibrator also would be needed. The effect of the time element for repeated stressing or the number of stress cycles on the redistribution of stresses is another factor to be considered.

The manufacturer recommends attaching the vibrator to a weldment and vibrating it at resonance for a certain period of time to obtain stress relief. Without having some background information on the above factors, little can be said regarding the extent of redistribution of stresses or stress relief that might occur in a given sample. One can only measure the stress distribution before and after vibrating the sample.

Residual stresses at and near metal surfaces can be measured by x-ray diffraction methods, which can be used as nondestructive tests.(3) Other methods for measuring stress patterns involve boring-out, slicing, or grinding procedures, all of which are generally destructive-type tests.(4,5) These techniques permit quantitative and/or qualitative residual stress analysis. Such techniques should be used in establishing the extent of stress relief or the degree of redistribution of stresses if use of vibratory methods is anticipated.

Information on the effect of resonant vibrations on residual stresses from reports and other literature sources is limited. Information from a German article by Bühler and Pfalzgraf has been reviewed and the following statement is made in the conclusions:(6)

> "Normally conducted vibrations do not suffice to reduce welding stresses because in this case the tension/compression loads involved are of an order of magnitude too low to generate a reduction in residual stresses. On the other hand, a reduction in residual stresses occurs....in the case of higher vibratory loading of the order of magnitude of the creep limit or fatigue strength.... In these cases also, one must test carefully to see there is no risk of fatigue fractures. In no case, however, is a state free from residual stresses obtained."

In a study made at Battelle by Dr. Koichi Masubuchi and Mr. F. A. Pimentel on the effect of vibration treatments and peening treatments in reducing the residual stresses in butt welded steel panels, the conclusions were as follows:[7]

> "Evaluation of strain measurements and stress calculations described in this report revealed no appreciable reduction in stress in either T-1 or mild steel weldments due to the ultrasonic stabilization or peening treatments."

In this study, sections were trepanned out of weld areas to establish the extent of residual stresses in treated and untreated panels.

Dr. Walter Starkey of Ohio State University, Mechanical Engineering Department, has studied stress relieving of metal components for one of his sponsors.[8] His studies were concerned with two effects of the mechanical vibrations: (1) on dimensional stability of machined parts after further machining and (2) on fatigue resistance. There was practically no effect of the process on dimensional stability as determined by machining tests both before and after vibration. There was a slight reduction in residual stresses as determined by fatigue measurements.

In reviewing preliminary tests on the effect of stress relieving by vibratory methods, Mr. Fred Houck of Ohio State University has reported the following results:[9]

> "As an example of such an operation, a welded structure was assembled in such a manner as to produce high stress levels. The part was studied, after welding, by x-ray diffraction methods and stress determined to be uniform in the range of 90,000 psi and nonuniform at 70,000 psi (approximate). The part was then subjected to vibration at resonance for a short period of time. Stress levels after vibration were agin measured and found to be 10,000 psi or less in both planes. The actual relieving operation was carried out in approximately 25 minutes. The initial testing was carried out for effect but was quite successful; further applications are being carried out for correlation and verification."

This research program is being continued to provide more conclusive evidence on the degree of stress relief and redistribution of residual stresses that can be achieved in weldments and forgings by vibration at resonant frequencies. The evidence indicates that considerable redistribution of stresses can be obtained. However, this can not be done effectively without a preliminary study of the components to be treated, the extent of residual stresses that exist in the critical areas, and the initial effects of the vibrational treatment.

Actually only a small amount of power is required to develop fairly high levels of cyclic stress at resonant frequency in most weldments and forgings. This is usually accomplished by attaching a small electric motor to the part to be vibrated. The motor has eccentric weights on the shaft which cause the dynamic vibrations as the motor shaft rotates. The speed of the motor is adjusted to achieve resonance. A similar method has been used in fatigue testing of large crackshafts. In vibrating welded components which may contain small cracks in the welds or some other form of

stress raiser at critical locations, the cracks and stress raisers can cause high stress concentrations at peak stress levels. Fatigue cracks could be initiated under certain conditions at these locations. Thus, the same forces that are intended to cause redistribution of residual stresses may cause crack growth by fatigue crack propagation. The extent of crack growth would depend on the number of stress cycles and the peak stress level. For this reason, it is recommended that nondestructive testing procedures be conducted both before and after any vibratory treatment of metal components.

In most weldments and hot and cold-formed components including rough-machined components, there are definite purposes in obtaining substantial stress relief throughout each of the components before further processing. According to the present state-of-the-art, this can be accomplished most successfully by thermal stress-relieving treatments. If some improvement in performance can be gained by developing desired residual stresses in a component, these residual stresses can be induced by shot peening, planishing, or other processes that may include vibration treatments. In each case, however, specific control of the process variables is required to achieve consistent results.

Even though the usual thermal stress relieving treatments often involve considerable time and cost, there is no known short-cut process that can achieve the same results as consistently and to the same degree of stress relief as thermal processing.

References

(1) "Vibrations Stress-Relieve 82-Ton Workpiece", Metalworking News (February 1, 1965).

(2) Murphy, John, "Vibrator Device Cuts Stress Relief Time", Metalworking News (March 15, 1965).

(3) Masubuchi, K., "Nondestructive Measurement of Residual Stresses in Metals and Metal Structures", Report RSIC-410, Redstone Scientific Information Center (April, 1965).

(4) Hetenyi, M., editor, Handbook of Experimental Stress Analysis, John Wiley and Sons, Inc., New York, New York (1950).

(5) Campbell, J. E., and McIntire, H.O., "How to Develop Favorable Stress Patterns" Part I, Iron Age (November 12, 1953).

(6) Bühler, Hans, and Pfalzgraf, Hans-Georg, "Investigations into the Reduction of Welding Stresses Brought About by Mechanical Vibration", Schweissen und Schneiden, 16, (5) p 178-184 (1964).

(7) Title of report and name of Sponsor are being withheld.

(8) Title of report and name of Sponsor are being withheld.

(9) Houck, Fred, "Putting Vibration to Work", Mechanical Engineering, 88, (9) p 48-5 (September, 1966).